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BATTLEFIELD AWARENESS AND DATA DISSEMINATION INTELLIGENT INFORMATION DISSEMINATION SERVER

Lockheed-Martin Corporation

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BATTLEFIELD AWARENESS AND DATA DISSEMINATION INTELLIGENT INFORMATION DISSEMINATION SERVER

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13. ABSTRACT *(Maximum 200 words)*
This report describe the research performed to design and develop software tools to facilitate the dissemination of battlefield data based on the Warfighter's needs and the ever changing world environment. The technology was conducted in collaboration with other researchers working on the DARPA/ISO Battlefield Awareness and Data Dissemination (BADD) initiative. This effort focused on capturing the Warfighter's information needs models, software that instantiates those information needs models with world information, and fundamental investigations into query merging. The prototype system augments the BADD Intelligent Data manger by improving both the accuracy and timeliness of "smart information push" delivering just the right data, to just the right place, at just the right time.

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ABSTRACT

This technology enhancement contract as part of the Battlefield Awareness and Data Dissemination (BADD) DARPA/ISO initiative has demonstrated key software tools to aid in the dissemination of battlefield data based on the Warfighter's needs and the changing world environment. The Lockheed Martin/Stanford University/University of Kansas effort has included assisting in the design and development of Warfighter information needs models, software that instantiates those information needs models with world information, and fundamental investigations into query merging. Our system has been designed to augment the BADD Intelligent Data Manager (IDM) by improving both the accuracy and timeliness of "smart information push" to WFAs. By applying these technologies, "smart push" delivers just the right data, to just the right place, at just the right time. This report summarizes our investigations.

INTRODUCTION

Information needed by the warfighter is available from many different sources and in many different formats: unstructured and semistructured text (e.g., news wires, intelligence reports, etc.), structured data in database systems (e.g., logistics and inventory databases), and image and video data (e.g., weather maps from satellites, area maps and battlefield snapshots from UAVs or fly-bys, etc.). All this information needs to be integrated into a comprehensive scenario called the "Battlefield Infosphere" [McCarthy95]. This scenario strives to provide the warfighter with a complete visual presentation of the combat area containing "layers" of information with friendly forces, enemy forces, weather factors, the air situation, and so on.

The Battlefield Awareness and Data Dissemination (BADD) system attempts to deliver to the warfighter the vast amount of information necessary to support this vision. An Information Dissemination Manager (IDM) determines what information to send over direct broadcast satellite to Warfighter's Associates (WFAs) in the field. We seek to augment the capabilities of the IDM with intelligence, that is, to design a representation language for user information needs profiling definition, to assist in the creation and maintenance of profiles, and to understand the issues in merging similar queries in order to utilize bandwidth resource effectively.

I3 APPROACH

DARPA's Intelligent Integration of Information (I3) program, underway since 1992, seeks to facilitate end-user and application program access to information by extracting, integrating, and abstracting information from data sources. The goal of an I3-based system is to provide seamless access to heterogeneous information sources. The vision is to facilitate the interoperation of distributed intelligent agents and their access to data.

IIDS APPROACH

Imagine the JFACC commander walking into his office each morning with the latest commander's brief on his computer desktop. It may include the descriptions of the major events from the past 24 hours, the progress of current missions, and any unusual new developments from red force movements to the buildup of a storm system. Backup information would be included to complete the picture of blue and red force positions, intelligence reports, and weather and road conditions. Information would be available in graphic forms: maps, images, and tables. Information about an encroaching storm system would be hyperlinked to weather maps and satellite images. Mission critical conditions would cause the inclusion of supporting data in the package with links to mission descriptions and assignments.

The Intelligent Information Dissemination Server (IIDS) is part of a larger effort that focuses on aspects of information management which will enable the scenario mentioned above, including:

- identifying and anticipating user information needs,
- aggregating information from heterogeneous information sources to satisfy the requirements,
- organizing the aggregated data into high-value multimedia and hyperlinked packages, and
- updating and prepositioning these information packages for use by the warfighter.

A user role or task implies certain information requirements. The IIDS represents these requirements as an *information profile* which can be expressed as parameterized high-level queries specialized by user or user-type. Below is an example of an information model for a Mechanized Infantry Unit.

> Get the *weather report* and *intel report* for the region where the unit is currently located. The *weather report* should include the basic *weather forecast* of *temperature*, *visibility*, and *precipitation* for the coming week, current *road conditions*, and a current *satellite weather map* of the region. The *intel report* should include information on *red force movements* within 50 kilometers."

Note that the information profile is composed of a set of object-oriented queries that represent the needs of a particular end-user and report type. In addition, each model is parameterized by user state phrases such as "at my current location," or "for the coming week." The objects in the query are grounded in domain terminology such as "satellite weather image" and "red force movements."

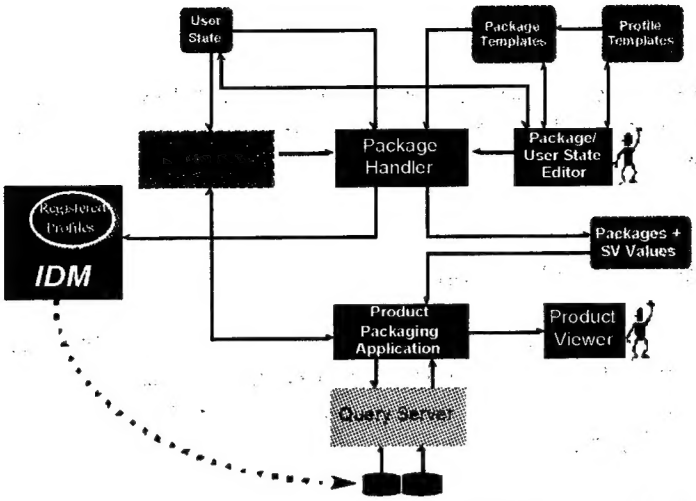

Figure 1. IIDS Functional Process

Figure 1 shows the functional process of the IIDS system. Using the user's current state (such as location, current mission, etc.) and the state of the world, the IIDS first specializes the profile by instantiating the user and world state parameters. This step may include adding information to the profile based on newly anticipated user information requirements due to important world events such as an encroaching storm or a dramatic movement in enemy troops. The second step towards information dissemination is the refinement of the query set implied by the information profile. During this step, the IIDS will determine how frequently to update the information package and whether or not the information is already available from a previously developed information package.

Another key aspect of information profiles in addition to having parameterized values is conditions. Conditions allow information to be retrieved when an arbitrarily complex condition occurs. Simple conditions such as:

- When the temperature in Sarajevo equals 95 degrees Fahrenheit, then...

To process more conditions, a local cache will have to store previous data values. This will enable conditions of the form:

- When the BDA status changes, then...
- When the inventory of widget X becomes less than 100, then...
- When the barometer in Sarajevo falls by more than 10% in a six hour period, then...

To execute profiles, the profile is first instantiated; all parameters in the profile are replaced with the appropriate values. Parameters allow significant flexibility in information profiles, allowing the individual queries to change dynamically based on a unit's changing location or mission as well as the changing world situation. After instantiation for each query in the profile, if there are no conditions and no variables to monitor then a query subscription is generated and sent to the information sources. For example,

Select weather.temperature

Where weather.location = "Sarajevo"

If a query has no conditions attached but has one or more variables needing to be monitored, a query subscription is generated, sent to the information sources as well as an additional subscription to monitor variable(s). For example,

Select weather.temperature

Where weather.location = ?myLocation

Finally, if a query has a condition attached, then a query subscription is generated for just the condition and any variables to monitor. The system checks the conditions upon retrieval of new data; should the condition become true, then a standard query subscription for the actual query is generated and sent to the information sources. For example,

Select targets.uav_image

Where targets.target = ?myTarget

(condition: Select targets.bda_status

Where targets.target_id = ?myTarget,

When bda_status changes)

The IIDS employs the sophisticated information access technologies developed in the DARPA Intelligent Integration of Information (I3) initiative to access and aggregate information from multiple heterogeneous information sources. Finally, information obtained from the data sources are organized into hyperlinked multimedia information packages and presented to the warfighter.

Architecture

The IIDS system consists of several software modules which communicate using a CORBA infrastructure to create, organize, and maintain information packages. Figure 2 shows the IIDS system components.

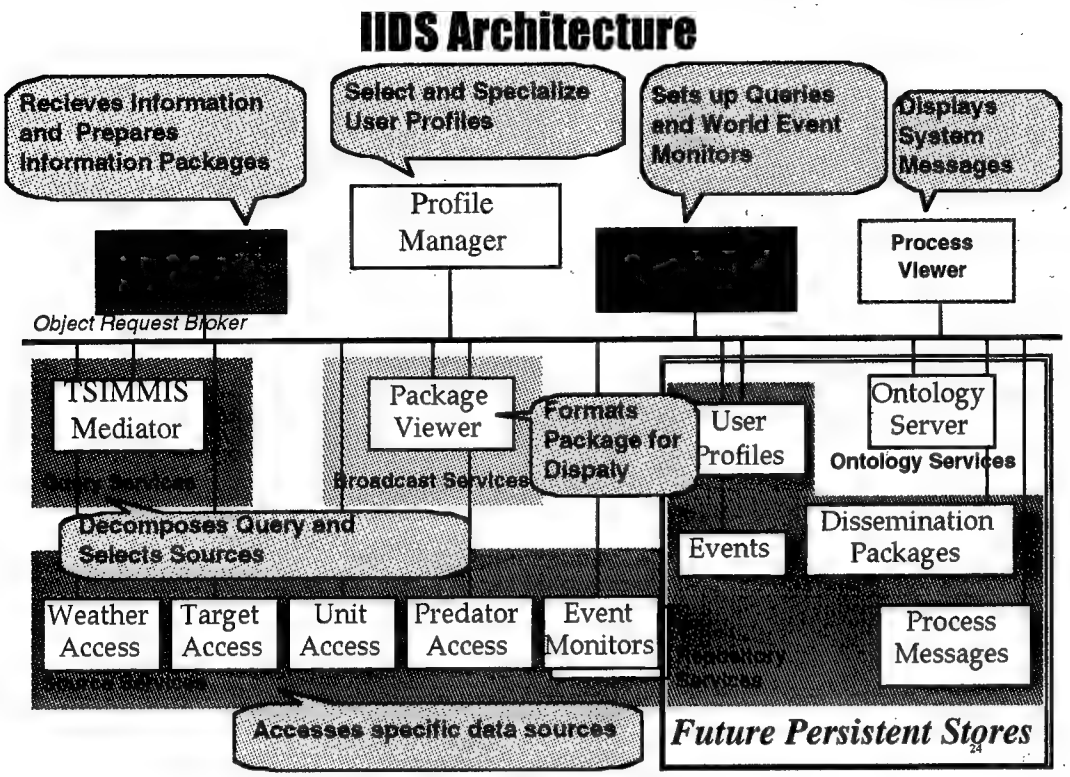

Figure 2. IIDS System Architecture

Anticipation

One of the key objectives of BADD is to disseminate just the right information to just the right units at just the right time. To accomplish this objective, IIDS attempts to anticipate future WFA information needs and thus reduce the need for explicit information requests from the field. In addition to the static model of information needs provided by a profile of each WFA, IIDS also provides an Anticipator module which accommodates dynamically changing information needs. Information anticipation can take the form of prepositioning information that the WFA will need soon or alerting the WFA to new information they need now but don't know to request it.

The anticipator updates only "active" profiles, i.e., profile instantiations currently in working memory in the Profile Manager. Profiles, as stored in the Profile Server, are not affected. In this way, the information needs for a particular WFA can be updated without affecting the profiles associated with other units (unless appropriate).

The Anticipator implements two types of anticipation of information needs: data-driven and information request-driven. In data-driven anticipation, the Anticipator monitors data sources for "significant" and "interesting" events. When such events are detected, a new query is created or an existing query is updated so that the new information can be sent to the relevant WFAs. The data sources monitored include world events related to the WFA such as the current status of the battlefield and enemy movements as well as the current status of the WFA such as its current location and mission objectives. The Anticipator also monitors other data sources which are of interest to the WFA, such as targets, weather, and terrain information. The method of monitoring data sources varies with the type of

source: either triggers are placed on certain data source values or the source is periodically queried. Results are sent to the Anticipator.

To determine the significance and resulting information needs effects of certain data source events, the Anticipator contains a rule base where each rule is an antecedent-action pair. Rule antecedents contain definitions of interesting and significant events. Thus, any event that matches a rule is deemed to be interesting. For example, an antecedent can specify "the number of enemy units within 100 kilometers increases by 5" or "the barometer decreases by 15% in a 6-hour period." When an interesting event is detected (i.e., a matching rule is found), the associated action is executed. The action specifies how to modify one or more WFA information profiles; the action specifies either a new query to be created or an existing query be modified.

The Anticipator also monitors explicit WFA information requests and uses this information to anticipate further WFA information needs. For each WFA, the Anticipator keeps a history of information requests, reasons about the relationships among the information requests, and reasons about the requests and how they interact with the status of the world and WFAs. In addition, the Anticipator also compares the information requests between different types of WFAs. A data mining engine is provided to find such relationships. Each information request from a WFA is distinguished by its contents such as data source names, attribute names and their values. The requests are then analyzed by the data mining engine to find relationships. Information request-driven anticipation can be useful for other purposes, such as updating the profiles of WFAs. In particular, the relationship between information requests and world events or WFA status can be used to update the rule base used to perform data-driven anticipation.

UNIVERSITY OF KANSAS ROLE

We completed the design of two Java software packages that are used in the implementation of our joint system, the Anticipator. The Anticipator in the BADD architecture is the component that is responsible for responding to and dynamically updating the information needs of users. Based on the occurrence of interesting events in the world, the Anticipator updates the information needs of users that are affected by those events.

Given data about the current state of the world, the first Java software package, called UserPackage, dynamically generates anticipation monitor queries for satisfying the information needs of appropriate users. As changes happen, the Anticipator either creates new monitors or removes existing monitors that are no longer needed.

To generate monitors dynamically, our system uses CLIPS rules. A set of rules is given facts about the world, and they generate OEM-formatted queries that are submitted to the data sources in the BADD architecture. To accomplish this task, we integrated a Java implementation of CLIPS into our system. Therefore, this approach enables the writing of monitor generation rules in an existing powerful rule language such as CLIPS.

The second software package, called OEM, supports the operations of the first one. It implements a library of classes for parsing, representing, and manipulating OEM objects embedded in strings. The library has been created as a general-purpose and stand-alone Java package that will be included as part of the Anticipator implementation for BADD.

It has full support for all OEM data types (integer, real, string, complex) except references, which are only partially supported in the current implementation. The classes OemInteger, OemReal, OemString, OemComplex, and OemReference represent their corresponding OEM-equivalent data types. The OemParser class is used to parse all types of OEM objects enclosed in strings and create appropriate Java representation for each parsed object. The OemComplex class is particularly of great importance, since it can represent non-atomic OEM objects with a hierarchy of arbitrary depth.

Both software packages are accompanied by their HTML documentation.

COMPARISON WITH OTHER WORK

The IIDS system is solidly based on past research from the Intelligent Integration of Information (I3) DARPA initiative. It is difficult to directly compare the IIDS system with others, because the IIDS system is an integration of multiple I3 efforts. Probably, the system that come closest to IIDS is Harvest [MicBowman95] developed by the Internet Research Task Force Research Group on Resource Discovery. It integrates tools to gather, extract, organize, search, cache, and replicate relevant information across the internet. Yet, the IIDS system distinguishes itself from Harvest in several aspects. The IIDS system accesses a wide variety of heterogeneous data sources compared to only web pages in Harvest. Also, Harvest does not provide a capability for anticipating information needs.

The IIDS approach of integrating multiple heterogeneous information sources can be contrasted with the SIMS [Arens93] approach from USC/ISI, also developed under I3. The goal of SIMS is to access multiple data sources using a single query language through optimal query planning and detailed knowledge about data sources. The IIDS approach is to sacrifice some optimal query planning for the sake of modularity, which facilitates integration. (Ease of integration of this approach has been demonstrated with the Loom-based matchmaker of Cosmos [Mark95], the MAX-based matchmaker of SHADE [Kuokka95], and IWSDB [Dukes-Schlossberg96]).

Ideas similar to the IIDS's information needs model are surfacing in work on information retrieval, digital libraries, and query reformulation [Fox95; Gladney94]. While most information retrieval systems are based on static data and dynamic query models, the IIDS's model is based on dynamic data and static queries. There is a growing need to anticipate the user's information needs. Recent systems with an anticipation capability include NLDB [Stevens92], work in concept space [Chen93], and GRANT [Cohen87]. The general idea is to start with an initial user profile and update the profile based on the user's responses to retrieved documents, using the approach similar to the IIDS's information anticipation (e.g., INFOSCOPE [Stevens92]).

On the other hand, very few systems accomplish data-driven anticipation and most of them rely on a query subscription capability of the underlying data sources [Widom96]. IIDS's Anticipator module uses event monitors to monitor sources in addition to the query subscription capability of data sources. It also uses a rule base to make inferences from results of these monitors.

RESULTS

Results from this effort included significant progress on the understanding and processing of warfighter information needs models. Together with ISX Corporation and USC/ISI, an integrated architecture was produced that tightly coupled profiling functionalities. Work progressed on all phases of

profiling: automated profile creation, user profile editing, profile processing, and automated profile maintenance. Further, these technologies were transferred to other DARPA and Lockheed Martin programs illustrating their significant benefit. Specifically, with the internally-funded Lockheed Martin fusion program, profiling is a major component and will impact the commercially-available Intelligent Library System™. Finally, Stanford University made significant progress on query merging analysis with a tool for visualizing and analyzing query merging strategies. They have examined query subscription merging in a distributed environment where multicast channels are used to deliver information. They have described methods for reducing the cost of delivering information by merging overlapping data in the query answers and by using the multicast channels effectively.

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[Widom96] J. Widom and S. Ceri (1996). "Active Database Systems: Triggers and Rules for Advanced Database Processing." Morgan Kaufman, San Francisco.

APPENDICES

Four technical papers are available that detail progress and results of this contract. The first is included below while the others are available from their URL's.

- Dukes-Schlossberg, Jon, Lee, Yongwon, Lehrer, Nancy. "IIDS: Intelligent Information Dissemination Server." Proceedings of MILCOM '97, Monterey, CA, November, 1997.
- Rys, Michael, Yau, K.-F. "Data Extraction from Dynamic Web Sites: Combining Crawling and Extraction." Available at: http://www-db.stanford.edu/~rys/papers/crawl.pdf.
- Crespo, Arturo, Buyukkokten, Orkut, Garcia-Molina, Hector. "Efficient Query Subscription Processing in a Multicast Environment." Available at: http://www-db.stanford.edu/pub/papers/badd.ps.
- Sevay, Huseyin, Tsatsoulis, Costas, Dukes-Schlossberg, Jon, and Lee, Yongwon. "A Knowledge-Based Approach to Anticipatory Intelligent Information Dissemination. Available at http://www.ittc.ukans.edu/~hsevay/papers/ieee/ieee-1998.ps.Z.

Appendix I
IIDS: Intelligent Information Dissemination Server

IIDS: INTELLIGENT INFORMATION DISSEMINATION SERVER

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ABSTRACT

Under initial funding from DARPA's Intelligent Integration of Information project, the IIDS[1] project team is enhancing the BADD Information Dissemination Server (IDS) to automatically filter and package information and to anticipate future Warfighter's Associate (WFA) information needs. Our enhancements to the IDS improve both the accuracy and timeliness of "smart information push" to WFAs. These enhancements are based on the insertion of information mediation, integration technologies, information source wrapping, and ontology modeling developed under the I3 program. By applying these technologies to the IDS, "smart push" delivers just the right data, to just the right place, at just the right time. This paper describes ttwo elements of the IIDS architecture: information anticipation and product packaging.

INTRODUCTION

Information needed by the warfighter is available from many different sources and in many different formats: unstructured and semistructured text (e.g., news wires, intelligence reports, etc.), structured data in database systems (e.g., logistics and inventory databases), and image and video data (e.g., weather maps from satellites, area maps and battlefield snapshots from UAVs or fly-bys, etc.). All this information needs to be integrated into a comprehensive scenario called the "Battlefield Infosphere" [McCarthy95]. This scenario strives to provide the warfighter with a complete visual presentation of the combat area containing "layers" of information with friendly forces, enemy forces, weather factors, the air situation, and so on.

The Battlefield Awareness and Data Dissemination (BADD) architecture attempts to deliver to the warfighter the vast amount of information necessary to support this vision. An Information Dissemination Server (IDS) determines what information to send over direct broadcast satellite to Warfighter's Associates (WFAs) in the field. We seek to augment the capabilities of the IDS with intelligence, that is, to anticipate future WFA information needs, to dynamically interact with information repositories, and to hyperlink information for ease of WFA interaction and drill-down.

I3 APPROACH

DARPA's Intelligent Integration of Information (I3) program, underway since 1992, seeks to facilitate end-user and application program access to information by extracting, integrating, and abstracting information from data sources. The goal of an I3-based system is to provide seamless access to heterogeneous information sources. The vision is to facilitate the interoperation of distributed intelligent agents and their access to data.

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[1] This work is supported by DARPA contract F30602-94-C-0192, monitored by Rome Laboratories. The views, opinions, and/or findings contained in this paper are those of the authors and should not be construed as an official Air Force position, policy, or decision, unless so designated by other documentation.

The Intelligent Information Dissemination Server (IIDS) focuses on aspects of information management which will enable the scenario mentioned above, including:

- identifying and anticipating user information needs,
- aggregating information from heterogeneous information sources to satisfy the requirements,
- organizing the aggregated data into high-value multimedia and hyperlinked packages, and
- updating and prepositioning these information packages for use by the warfighter.

A user role or task implies certain information requirements. The IIDS represents these requirements as an *information profile* which can be expressed as parameterized high-level queries specialized by user or user-type. Below is an example of an information model for a Mechanized Infantry Unit.

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Note that the information profile is composed of a set of object-oriented queries which represent the needs of a particular end-user and report type. In addition, each model is parameterized by user state phrases such as "at my current location," or "for the coming week." The objects in the query are grounded in domain terminology such as "satellite weather image" and "red force movements."

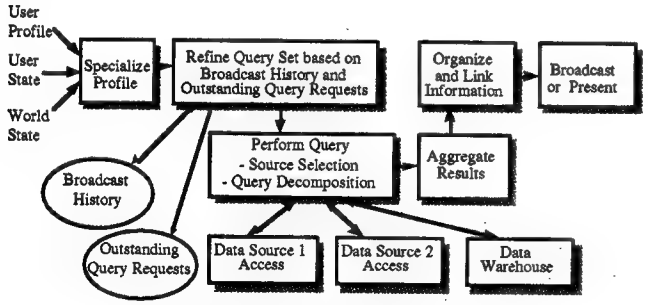

Figure 3. IIDS Functional Process

Figure 1 shows the functional process of the IIDS system. Using the user's current state (such as location, current mission, etc.) and the state of the world, the IIDS first specializes the profile by instantiating the user and world state parameters. This step may include adding information to the profile based on newly anticipated user information requirements due to important world events such as an encroaching storm or a dramatic movement in enemy troops. The second step towards information dissemination is the refinement of the query set implied by the information profile. During this step, the IIDS will determine how frequently to update the information package and whether or not the information is already available from a previously developed information package.

The IIDS employs the sophisticated information access technologies developed in the DARPA Intelligent Integration of Information (I3) initiative to access and aggregate information from multiple heterogeneous information sources. Finally, information obtained from the data sources are organized into hyperlinked multimedia information packages and presented to the warfighter.

Architecture

The IIDS system consists of several software modules which communicate using a CORBA infrastructure to create, organize, and maintain information packages. Figure 2 shows the IIDS system components.

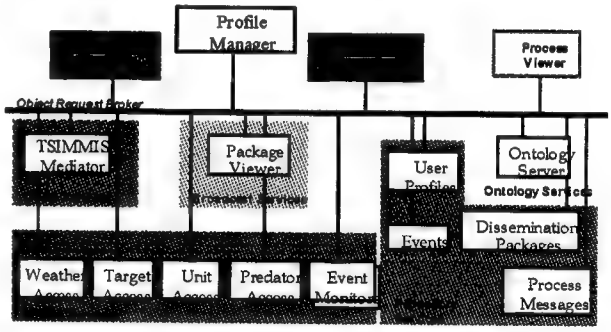

Figure 4. IIDS System Architecture

Profile Manager. Manages user profiles and generates information requests by instantiating profile variables. Also responsible for anticipating additional user needs due to world events such as an encroaching storm or a dramatic change in the battlefield.

Event Manager. Manages and arbitrates the frequency and type of information requests that are sent to the Query Services. Information requests are managed based on user requirements for information updates and based on the availability of information due to other information package requests.

Package Manager. Organizes information received from the Query Services into high-value, hyperlinked information packages. Information package formats may be defined by the user profile or may be determined by the Package Manager using heuristic rules.

Query Services. Decomposes high level queries into a set of queries which can be satisfied by a single source. Each query is directed to a specific information source. The results are aggregated and returned to the Package Manager.

Source Services. Creates a unified interface into heterogeneous types of information sources.

The remaining modules, such as the Repository Services and Ontology Services are planed for future releases of the IIDS.

Figure 3 illustrates the interaction of the Profile Manager, Event Manager, Query and Source Services and the Package Manager. Following the functional requirements pictured in

Figure 1, the Profile Manager begins by notifying the Package Manager to begin a package designated for a particular user. The Event Manager is notified of the specific information requests needed to fill the package. The Event Manager requests queries at appropriate intervals to the Query Server. The Query Server uses the Source Services to obtain the information and sends the results onto the waiting Package Manager. The results, as they are received are organized and made available for presentation to the warfighter.

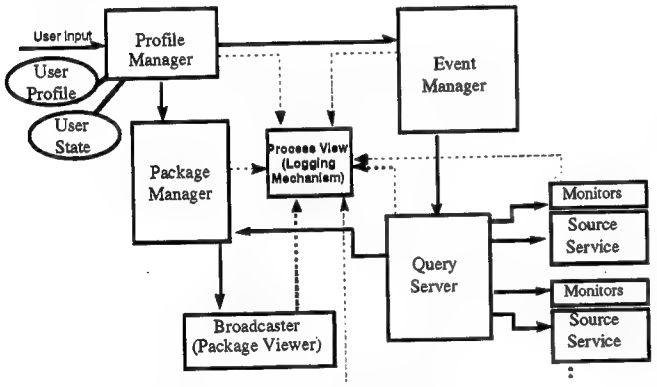

Figure 5. IIDS Process Flow

Anticipation

One of the key objectives of BADD is to disseminate just the right information to just the right units at just the right time. To accomplish this objective, IIDS attempts to anticipate future WFA information needs and thus reduce the need for explicit information requests from the field. In addition to the static model of information needs provided by a profile of each WFA, IIDS also provides an Anticipator module which accommodates dynamically changing information needs. Information anticipation can take the form of prepositioning information that the WFA will need soon or alerting the WFA to new information they need now but don't know to request it.

The anticipator updates only "active" profiles, i.e., profile instantiations currently in working memory in the Profile Manager. Profiles, as stored in the Profile Server, are not affected. In this way, the information needs for a particular WFA can be updated without affecting the profiles associated with other units (unless appropriate).

The Anticipator implements two types of anticipation of information needs: data-driven and information request-driven. In data-driven anticipation, the Anticipator monitors data sources for "significant" and "interesting" events. When such events are detected, a new query is created or an existing query is updated so that the new information can be sent to the relevant WFAs. The data sources monitored include world events related to the WFA such as the current status of the battlefield and enemy movements as well as the current status of the WFA such as its current location and mission objectives. The Anticipator also monitors other data sources which are of interest to the WFA, such as targets, weather, and terrain information. The method of monitoring data sources varies with the type of source: either triggers are placed on certain data source values or the source is periodically queried. Results are sent to the Anticipator.

To determine the significance and resulting information needs effects of certain data source events, the Anticipator contains a rule base where each rule is an antecedent-action pair. Rule antecedents contain definitions of interesting and significant events. Thus, any event that matches a rule is deemed to be interesting. For example, an antecedent can specify "the number of enemy units within 100 kilometers increases by 5" or "the barometer decreases by 15% in a 6-hour period." When an interesting event is detected (i.e., a matching rule is found), the associated action is executed. The action specifies how to modify one or more WFA information profiles; the action specifies either a new query to be created or an existing query be modified.

The Anticipator also monitors explicit WFA information requests and uses this information to anticipate further WFA information needs. For each WFA, the Anticipator keeps a history of information requests, reasons about the relationships among the information requests, and reasons about the requests and how they interact with the status of the world and WFAs. In addition, the Anticipator also compares the information requests between different types of WFAs. A data mining engine is provided to find such relationships. Each information request from a WFA is distinguished by its contents such as data source names, attribute names and their values. The requests are then analyzed by the data mining engine to find relationships. Information request-driven anticipation can be useful for other purposes, such as updating the profiles of WFAs. In particular, the relationship between information requests and world events or WFA status can be used to update the rule base used to perform data-driven anticipation.

Product Packaging

The Package Manager is responsible for orchestrating the processing of information packages through the Data Policy and the Display Policy. The Data Policy manages information about the data in the package and the semantic relationships between its components. The Display Policy organizes the information based on user preferences, semantic hyperlinking and human factors concerns. Figure 4 presents the architecture of the Package Manager.

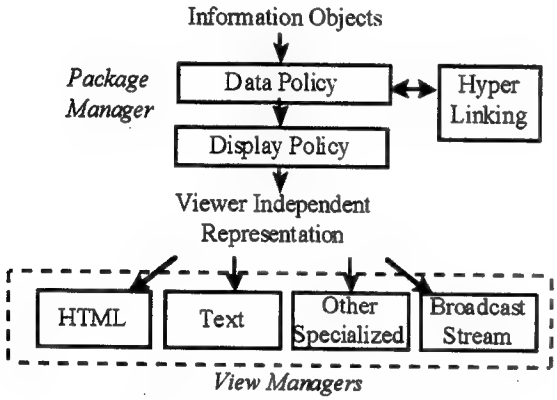

Figure 4. Package Manager Architecture

The Data Policy organizes and links information contained in the package in two ways: 1) based on user-defined relationships and 2) based on data value relationships. Information is initially organized based on user provided guidance. For example, the user can specify that a set of information about the weather is to be formatted as a table each row containing a set of data, or as a list of records each record containing all the weather information about a particular city. The Package Manager will allow for both highly specified organizations (e.g., put the weather in a table with the columns labeled "Location," "Temp," etc.) or the specification can be general allowing the Package Manager to use information from the domain ontology and human factors to determine the organization. For example, if the profile simply stated to put the weather in a table, the Package Manager would use the organization of the attributes of weather as defined by the domain ontology to determine an order for the columns in the table. Figure 5 illustrates the Data Policy for the IFOR Headquarters Information Package.

The purpose of the Display Policy is to ensure that the representation of the data that has been accumulated in the Package, for a particular user, is readable and consistent. The Display Policy does three things: 1) applies user-supplied display preferences, 2) constructs an index record based on the links found during the Data Policy phase, and 3) transforms the information package into a display independent form for use by one or more View Managers. The representation provided to the view manager will indicate some metadata semantics about the information (e.g., "Here is the Weather information"), but mostly it will contain a display description for the information so that the View Manager needs no information about the semantics of the data contained in the package.

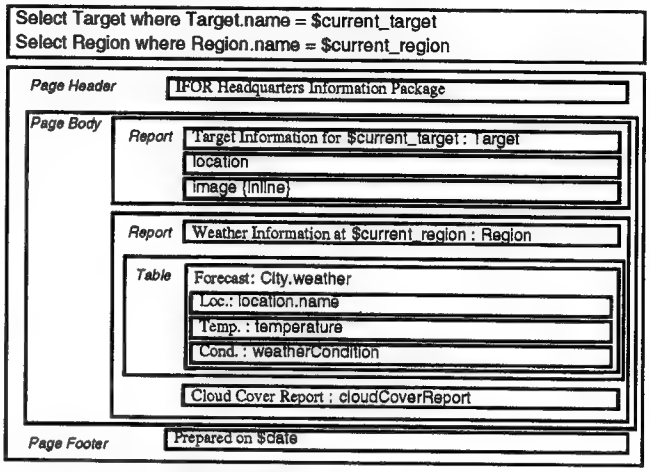

Figure 5. Information Package Data Policy

Once managed by the Package Manager, the information package is represented in a display independent form. The IIDS team is in the process of developing package viewers to view these packages in multiple ways on multiple platforms. It is important to support users with various capabilities. For example, some end-users will be able to view packages on a platform with high resolution graphics and a fast internet connection. To these users an HTML view might be most appropriate. Other users, however may have high resolution graphics capabilities, but be on a platform with low bandwidth connectivity to the network. For these users, the IIDS will support viewing the package through an HTML-no-image viewer. The IIDS will also support text-only on the low-end, and other forms of highly interactive views on the high-end. These high-end viewers could include interactive Java or VRML screens.

COMPARISON WITH OTHER WORK

The IIDS system is solidly based on past research from the Intelligent Integration of Information (I3) DARPA initiative. It is difficult to directly compare the IIDS system with others, because the IIDS system is an integration of multiple I3 efforts. Probably, the system that come closest to IIDS is Harvest [MicBowman95] developed by the Internet Research Task Force Research Group on Resource Discovery. It integrates tools to gather, extract, organize, search, cache, and replicate relevant information across the internet. Yet, the IIDS system distinguishes itself from Harvest in several aspects. The IIDS system accesses a wide variety of heterogeneous data sources compared to

only web pages in Harvest. Also, Harvest does not provide a capability for anticipating information needs.

The IIDS approach of integrating multiple heterogeneous information sources can be contrasted with the SIMS [Arens93] approach from USC/ISI, also developed under I3. The goal of SIMS is to access multiple data sources using a single query language through optimal query planning and detailed knowledge about data sources. The IIDS approach is to sacrifice some optimal query planning for the sake of modularity, which facilitates integration. (Ease of integration of this approach has been demonstrated with the Loom-based matchmaker of Cosmos [Mark95], the MAX-based matchmaker of SHADE [Kuokka95], and IWSDB [Dukes-Schlossberg96]).

Ideas similar to the IIDS's information needs model are surfacing in work on information retrieval, digital libraries, and query reformulation [Fox95; Gladney94]. While most information retrieval systems are based on static data and dynamic query models, the IIDS's model is based on dynamic data and static queries. There is a growing need to anticipate the user's information needs. Recent systems with an anticipation capability include NLDB [Stevens92], work in concept space [Chen93], and GRANT [Cohen87]. The general idea is to start with an initial user profile and update the profile based on the user's responses to retrieved documents, using the approach similar to the IIDS's information anticipation (e.g., INFOSCOPE [Stevens92]).

On the other hand, very few systems accomplish data-driven anticipation and most of them rely on a query subscription capability of the underlying data sources [Widom96]. IIDS's Anticipator module uses event monitors to monitor sources in addition to the query subscription capability of data sources. It also uses a rule base to make inferences from results of these monitors.

STATUS

Currently, IIDS personnel are interacting with representatives of the Bosnia Command and Control Augmentation force (BC2A). BC2A personnel at the Joint Information Management Center (JIMC) are managing the current deployment of BADD technology in Bosnia and are very interested in exploring IIDS technologies and providing domain expertise to stress our ideas. We have also had interactions with the BADD integration contractor, CDI. In the future, both Lockheed Martin and ISX Corporation are continuing the IIDS work under BADD technology enhancement funding. IIDS project enhancements include a more robust implementation of information anticipation, profiles, and product packaging.

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